Production of Pre-separated Short-lived Isotopes of Lighter Homologs of Transactinides for Chemistry Experiments

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Using pre-separated isotopes for chemical studies of transactinides (TAN, Z ≥ 104) is desirable in many cases, e.g., when byproducts of the nuclear reaction interfere with the unambiguous identification of the TAN under investigation [1] or when plasma formation due to the intense heavy-ion beam in the gas volume where the nuclear reaction products are thermalized is unacceptable, e.g., when working with organic compounds [2]. To rule out the role of differing experimental conditions in the measurement of chemical properties, it is desirable to investigate isotopes of all homologs simultaneously. Due to their different magnetic rigidities, the Berkeley Gas-filled separator (BGS) can not forward them to the chemistry setup simultaneously. The next best approach is to quickly switch between short-lived isotopes of these elements without opening the chemistry setup. This can be realized by producing these isotopes in heavy-ion induced fusion reactions employing beams of similar A/Q and E/A which can be accelerated simultaneously in a cyclotron. This technique is referred to as a heavy-ion cocktail and is extensively used at the 88-inch cyclotron for the radiation effects testing program [3].

In order to produce short-lived Zr and Hf isotopes, the nuclear reactions ^{nat}Ge(^{18}O,*x*n)^{85}Zr, and ^{112,116,120,124}Sn(^{50}Ti,*x*n)^{158,161,165,169}Hf were chosen. The parameters of the cocktail beams are given in Table 1.

Using this cocktail and a target ladder holding up to 5 targets, which can be remotely introduced into the path of the beam, allowed for a quick switching between Zr and Hf. Magnetic rigidities for all produced isotopes were measured; see Table 2.

The residual range of ^{169}Hf and ^{85}Zr in Mylar, which is used as the BGS exit window was measured and compared to SRIM2003 [4]; see Figure 1.

TABLE 1: Parameters of the cocktail beam. *f* is the cyclotron frequency at the 88-inch cyclotron.

Ion	Q	A/Q	E [MeV]	MeV/n	*f* [MHz]
^{18}O	4+	4.5	83.6	4.654	14.5162
^{50}Ti	11+	4.54	228.0	4.565	14.3875

TABLE 2: Velocities v (in units of the Bohr velocity v_0) and magnetic rigidities Bρ for isotopes produced in reactions of the beam B with the target T at beam energies of about 83 MeV (^{18}O) and 223 MeV (^{50}Ti).

B	T	EVR of interest	v/v_0	Bρ [T·m]
^{18}O	^{nat}Ge	^{85}Zr (7.86 min)	2.7-2.8	0.92
^{50}Ti	^{112}Sn	^{158}Hf (3.2 s)	4.13	1.40
^{50}Ti	^{116}Sn	^{162}Hf (37.6 s)	4.05	1.44
^{50}Ti	^{120}Sn	^{165}Hf (76 s)	3.95	1.50
^{50}Ti	^{124}Sn	^{169}Hf (3.24 min)	3.86	1.54

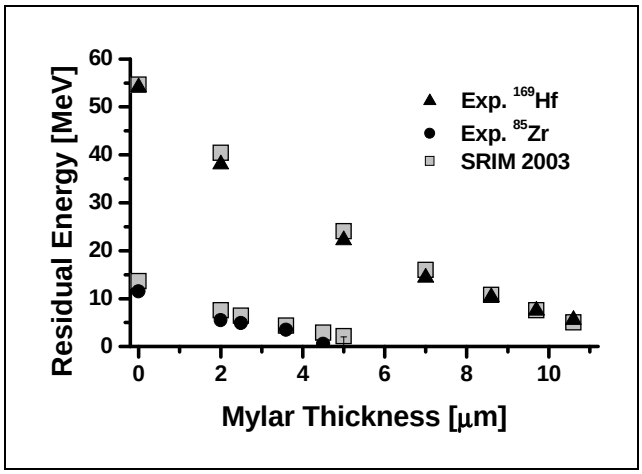

FIGURE 1: Residual energy of ^{169}Hf and ^{85}Zr after passing through Mylar. The pulse-height correction from [5] was used.

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